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PRIMORDIAL NUCLEOSYNTHESIS AND DIRAC'S LARGE NUMBERS HYPOTHESIS

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ABSTRACT

It is shown that a recent analysis concerning the amount of primordial helium produced within the scale covariant cosmology is based on two invalid extrapolations.

Subject headings: cosmology — nucleosynthesis

I. INTRODUCTION

In a recent *Letter*, Falik (1979) claimed that the cosmological model proposed by Canuto and Hsieh (1978), which incorporates the possibility of a time-varying gravitational constant G, does not allow for the synthesis of primordial helium, and suggested that the model contradicted observation. We show that his conclusion rests on two invalid extrapolations of the scale covariant theory of gravitation (SCT) used to develop the cosmological model.

II. THE FIRST EXTRAPOLATION

Falik assumed that even when G is a function of time, the following relations hold, as in the standard theory (see, e.g., Weinberg 1972):

$$\rho_\gamma \sim T^4 ; \quad RT = \text{constant} , \tag{2.1}$$

where ρ_γ is the energy density of radiation in local thermodynamic equilibrium, T is the equilibrium temperature, and R is the scale factor of the Robertson-Walker metric. Because of an implicit homogeneity assumption, all the quantities in (2.1) are functions of the cosmological time t only.

Canuto and Hsieh (1979) have shown that within the framework of the SCT, the correct relations are

$$\rho_\gamma \sim \beta^2 G^{-1} T^4 ; \quad \beta RT = \text{constant} . \tag{2.2}$$

The function β is determined (a) by imposing a gauge condition, giving a relation between β and G; and (b) by stipulating the time variation of G. Examples of (a) and (b) are given by (Canuto and Hsieh 1978; Dirac 1937)

$$\beta^2 G = \text{constant} \tag{2.3}$$

and

$$G \sim t^{-1} . \tag{2.4}$$

It is easy to see that the only way to make equations (2.1) consistent with the SCT is to have G = constant and β = constant. Hence the numerical estimates of Falik (1979), based on equation (2.1), are irrelevant to the cosmological model of Canuto and Hsieh (1978), which is based on the gauge condition (2.3).

III. THE SECOND EXTRAPOLATION

Falik (1979) assumed equation (2.4) to be valid even at early cosmological epochs when primordial nucleosynthesis took place. Using the relations (2.2), (2.3), and (2.4), together with equation (2.9a) of Canuto and Hsieh (1978), it follows that (cgs units)

$$tT^{4/3} = 10^{19} , \tag{3.1}$$

which implies that at a temperature of 10^9 K, when deuterium and helium can form, the cosmological age was 10^7 s. Since this is considerably longer than the neutron lifetime, 10^3 s, one concludes that there would have been no neutrons for the formation of primordial helium.

Equation (3.1) is however based on (2.4) which Dirac (1937, 1978) has repeatedly stressed to be only an asymptotic form valid for large cosmological times. Hence the above conclusion cannot be held against either the particular cosmological model of Canuto and Hsieh (1978) or the SCT in general.

Finally, we note that the relation (2.4) has been shown to be compatible with observations pertaining to the matter-dominated universe (Canuto, Hsieh, and Owen 1979; Canuto and Owen 1979).

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